

The Indiana Network for Patient Care: An Integrated Clinical Information System Informed by Over Thirty Years of Experience

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Presented in this article is the Indiana Network for Patient Care, an integrated citywide medical record system that promotes health quality by enabling efficient access to clinical information. It begins with a description of the system's infrastructure, which includes an explanation of how the system accomplishes data integration. This is followed by a series of descriptions and rationales behind the many clinical applications that interface these data. In doing so, some of the factors that we feel contribute to the success of the system are illustrated.

KEY WORDS: computerized information systems, diffusion of innovation, medical record systems

The field of medical informatics endeavors to improve health care by enabling efficient access to information. Care providers use this information, whether as medical knowledge or patient data collected during clinical care, to make decisions and ensure appropriate standards of care. The Regenstrief Institute has worked for many years to integrate disparate clinical data sources through the development of the Indiana Network for Patient Care (INPC). This citywide clinical informatics network is our ongoing attempt to leverage the successes of the Regenstrief Medical Record System (RMRS) throughout the broader population of Indianapolis and the rest of the caregivers within the state of Indiana.

The creation of the RMRS traces back to 1972, when we conceptualized and began construction of a computerized patient management system for outpatient diabetes care.¹ Our goals in building this system were threefold.² First, it was designed to eliminate the logistical problems inherent in paper records by making clinical data available to authorized users "just-in-time"³ as

medical decisions are made. It was also meant to assist in the recognition of diagnoses and pertinent preventive care by assisting clinicians in the record keeping process. Finally, we intended the system to aggregate clinical information for public health, epidemiologic, outcomes, and management research.⁴ We believe the successful evolution of the RMRS into the INPC is due in part to our persistent dedication to these prescient goals. Thirty years later, these goals continue to inform our efforts as we advance our system's infrastructure. What follows is our description of the present day INPC.

● The Indiana Network for Patient Care

Participants and scope

The metropolitan statistical area (MSA) of Indianapolis is defined by 9 counties that all closely integrate with the central downtown region. The INPC medical record system is operational in all major health care systems within this MSA. All 5 major hospital systems serve in this capacity, including Community Hospitals of Indianapolis, St. Vincent Hospitals and Health Services, St. Francis Hospital and Health Centers, Clarian Health Hospitals, and Wishard Health Services. Additionally, INPC includes 4 Marion County homeless care organizations, all county and state public health departments, primary care providers at 20 sites, 3,000 specialists, and 30 public school clinics. In all, INPC

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members cover over 95% of acute inpatient and non-office based outpatient clinical care within the MSA, including greater than 390,000 emergency room⁵ and 165,000 inpatient visits, and over 2.5 million clinic visits per year. Participants contribute more than 50 million laboratory results per year and all inpatient and emergency encounter summaries to the INPC, which consist of admission and discharge summaries, operative notes, radiology reports, pathology reports, and inpatient medication data. Some participants also contribute radiology data, cardiology studies, outpatient medication lists, and pharmacy prescription data. In addition, the system exchanges public health data, including tumor and immunization registry data, with both the Marion County and Indiana State health departments.

Base infrastructure

At its core, the INPC is a series of federated database “vaults” located at the Regenstrief Institute.^{6,7} Each INPC participant contributes data to these vaults by sending selected data elements from their proprietary electronic medical record systems over high-speed secured connections. These real-time data streams are transmitted in HL7, the nationally recognized clinical messaging standard (Health Level Seven, Inc., Ann Arbor, Michigan). Although all institutional INPC data vaults are currently maintained at the Regenstrief facilities, each institution has administrative authority over their content and the system is designed to accommodate vaults in remote locations.

In order to efficiently normalize content between institutions, all vaults share the same database structure and standardized terminology.⁸ Much like a dictionary defines the function, meaning, and relationships of words, our “concept dictionary” defines the names, codes, and other attributes for all medical tests, drugs, and coded results contained in the INPC. Using this dictionary, synonymous terms from different institutions are mapped to the same concept. Those concepts are standardized according to type: LOINC[®] for laboratory results,^{9,10} CPT-4 for procedure names,¹¹ ICD-9 for diagnoses,¹² and National Drug Codes (NDC) and RxNorm for medications.^{13,14} Once standardized, data is linked to the patient and stored in the appropriate institution-specific medical record vault.

The system interconnects a patient’s data from separate vaults via a centrally managed global patient registry. Because access to clinical data is tightly coupled to the patient, accurate patient identification is vital to the success of our integrated regional health information network. We have developed mechanisms that perform the critical and complex task of defining patients uniquely by “linking” patient identifiers from

separate institutions to a single global ID. Our system performs this task by utilizing a series of progressively fuzzy matching algorithms¹⁵ that act on demographic variables including patient name, social security number, birth date, and gender. A similar physician and provider registry maintains the index of health care providers contributing to and using data from the INPC.

Clinical application modules

The technologies described above create a patient-specific virtual medical record. This electronic profile is an aggregation of all content encoded by the participating sites for a given patient. We can harness the power inherent in a virtual medical record through a series of clinical application modules designed to interface with this information.

Results inquiry

We designed the Inquiry application to serve as the basic electronic “window” from which caregivers can review patient-specific medical record data. Practitioners reap significant time and resource advantages when they reference patient data this way. Not only is electronic data location independent and ubiquitous, but it can be efficiently navigated through search technologies and customizable user interfaces. We have developed successive generations of this application that take advantage of the capabilities of modern desktop computers. The most recent version of this application is Web-based and allows users to access both textual and multimedia content. Web Inquiry has the ability to display data ranging from lab results and typed progress notes to X-ray images, EKG tracings, and cardiac ultrasound videos.

Inherent in Web Inquiry are many features that add value to the data browsing experience. The application can generate flowsheets that assist caregivers in understanding data’s temporal relationships. Laboratory results from multiple hospitals are collated into unified, patient-specific views. Medical knowledge resources, such as *PubMed* and the National Guideline Clearinghouse (<http://www.guidelines.gov>), are hyperlinked to specific points of clinical content through “infobuttons.”¹⁶ All of these features are deployed throughout our network via secure connections to personal computers with Web browsing capabilities.

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Patient abstracts/encounter forms/pocket rounds

Our Results Inquiry module provides caregivers with clinical data “one stop shopping.” The comprehensive information this application provides, while often necessary in task completion, has the potential to overwhelm caregivers in well-circumscribed scenarios. For example, it’s probably unimportant to inform a clinician that his patient’s cholesterol level is normal when he’s merely come in to have a laceration repaired. As data continues to accumulate within the INPC, there are increasing demands to provide concise subsets of filtered medical record data for specific care scenarios. We have developed a few modules to provide these “clinical snapshots” to caregivers in very workflow friendly ways.

One of these modules generates patient abstracts, which are paper-based documents designed to provide pertinent patient-specific data in outpatient settings. These documents are customized for clinical locations and specialties to fill the unique needs of these entities. For example, the “infant” abstract provides newborn screening results, maternal health history, and data tied to the delivery event. The “pediatric” abstract on the other hand provides immunization histories along with growth and development data. The encounter form is another tailored document that often accompanies the patient abstract. This form, intended to aid in the practitioner’s documentation process, contains pertinent alerts, reminders, a list of previously noted problems, and general demographic information for a given patient.

Tailored documents have also proven very useful (and popular) in hospital inpatient settings. Pocket Rounds¹⁷ are documents designed to eliminate the cumbersome and time-consuming tasks involved when clinicians attempt to summarize a patient’s course of action throughout a hospitalization. These printed reports, like the 3 × 5 “scut” cards that inspired them, provide a very compact overview of the patient’s state. They include lists of active orders, problems, allergies, a flowsheet of recent laboratory results, vital signs, and a listing of the interpretations of recent imaging studies and other diagnostic tests.

The medical gopher

Inherent in the process of medical decision making are burdensome tasks that consume significant portions of a caregiver’s work day. Practitioners spend much of their time finding, organizing, and reviewing data before deciding on a specific course of action. These processing chores are often humorously referred to in the medical community as “scut” or “gopher” tasks. We built the Medical Gopher in 1984 to facilitate this care giver inefficiency and inform decision making by

serving as an electronic intermediary.¹⁸ The Gopher is a computer workstation designed to accept and process medical orders and tasks. It provides facilities for entering prescriptions, orders, problems, and other medical information. In return, the Gopher provides the user with hints, reminders, alerts, and rapid access to information related to that entry.

Data already available in the patient’s electronic medical record often significantly impacts this process. For example, there are certain medicines that would be inappropriate for people with kidney disorders. Previous practitioners might have already followed a diagnostic pathway actively being considered. Allergies may preclude the use of chemical agents given to enhance the detail of radiological tests. Immunizations that children routinely receive may be missing. Each of these vignettes illustrate how medical record data when provided “just in time” impact decision making and enhance Gopher functionality.^{19,20}

Twenty years ago, the Gopher was very much an experiment, as the first computerized order entry system used in outpatient care. Subsequent research of the system has demonstrated significant, measurable improvements in care efficiency^{18,21} and quality.²² Probably more importantly, practitioners in our community embrace the system and foster its continued development.

DOCS4DOCS®

Because patient data is routinely distributed across separate databases and systems, both within and among organizations as separate islands,²³ health care providers are often encumbered by the increased record keeping burden this reality brings. Receiving clinical data and test results in many different formats from multiple information sources brings logistical headaches and occupies time intended for direct patient interaction. In 2002, DOCS4DOCS® was built to address this problem by efficiently delivering aggregated clinical results to physicians regardless of where they practice throughout the INPC. This innovative system facilitates standardized automated results delivery by formatting, aggregating, and conveying information in a consistent fashion. It dynamically generates customized reports that a practitioner can quickly review and act upon. Reports can be delivered through multiple mediums, including network printer, Web browser, email, or fax. The system is also capable of serving as a “virtual filing cabinet,” giving practices and practitioners a pre-organized, short-term results storage system. In addition, the system contains auditing functions that allow results that have been reviewed to be fully annotated.

Since its inception 2 years ago, DOCS4DOCS® has been deployed to over 800 physicians and continues a

broad rollout throughout the Indianapolis area. It has expanded its mission to provide results delivery service to the entire Indianapolis health care community. Without the existing INPC technical infrastructure, which is built on a foundation of standardized data streams, such rapid implementation would not have been possible.

Child Health Improvement through Computer Automation (CHICA)

Providing decision support in outpatient settings is often hindered by the tight workflow constraints, inherent with high patient volumes and well established practice patterns. In addition, many medical decisions hinge on real-time patient information: retrospective data insufficiently informs the process. CHICA was designed from its outset to address these demands by providing those required “just-in-time” clinical pieces to practitioners via a familiar, flexible paper interface.²⁴ We’ve designed this particular system to poll both patients and support staff directly through the use of Adaptive Turnaround Documents (ATDs). These patient-specific, computer interpretable paper forms accurately and efficiently capture handwritten data entry through document scanning and optical character recognition technologies.^{25,26} HL7 interfaces to both the clinical repository and the patient registration system allow CHICA to dynamically generate an ATD screening questionnaire to be completed by families upon arrival to the clinic. The information captured on these forms coupled with data contained within the medical record allow CHICA to print clinical alerts and reminders on a physician encounter ATD, along with relevant patient handouts. Interacting this way with practitioners allows our medical record system to both inform and be informed in a way that’s exquisitely sensitive to workflow constraints.

Fast Retrieval and the CARE language

Our health care network is peppered by clinicians, researchers, and epidemiologists alike who all have interest in addressing broader health care questions. As our integrated data repository has matured, it has evolved into a rich “clinical mine” that affords these people unique opportunities to synthesize new medical knowledge through retrospective data analysis. Fast Retrieval and the CARE language serve as the electronic “pickaxes” that facilitate this process.

Both of these modules allow one to cull data from the repository by defining search criteria based on demographic (eg, age, gender), observational (eg, weight, laboratory test result), and diagnostic (eg, iron deficiency anemia, asthma) criteria. They accomplish these tasks, however, through different means. To serve the

needs of busy clinicians and novice users, Fast Retrieval is designed to give quick answers and “first looks” at queries. Through the extensive use of database indexing and a user-friendly interface, this application has the capability to provide rapid results. CARE, on the other hand, is a query language designed to give researchers opportunities to build complex queries on a larger subset of both structured and unstructured content within the database. Users build and compile scripts that are used to generate datasets.

Reportable diseases module

As the catchment area of the INPC is fed by larger geographic regions, our system is more plausibly used as a means of ensuring public health. The reportable disease module demonstrates how integrating data allows us to serve as an integral partner in this regard.

Public health departments have long collected aggregated statistics for concerning medical conditions as a means of monitoring unusual or notable deviations in the health of its population. It’s challenging for these groups to build robust datasets, as most rely heavily on manual, volunteer reporting. In other words, practitioners and health care facilities alike must make deliberate efforts to inform public health databases.

The INPC system attempts to address this shortcoming by deriving this information from content already reported to us by our network and automating communication of this content to public health.⁴ The reportable disease module produces a database combining reportable condition data, patient demographic data derived from hospital registration systems, and INPC provider information. Each day the system transfers the reportable condition database to the Indiana State Department of Health and Marion County Health Department using a secure, private network. Concomitantly, Regenstrief investigators and several interested county and state public health officials receive a daily email summary of recent reportable conditions.

A recent analysis comparing the INPC’s electronic laboratory reporting component with traditional reporting methods revealed that the INPC system captured up to 5 times more data than traditional paper- or fax-based reporting methods and conveyed information in the most timely fashion across a broad spectrum of reportable diseases.

● Keys to Success

We’ve had good fortune in our infrastructure developments over the past 30 years. As we reflect on the highlights that have successfully shaped the INPC into what it is today, some primary themes have emerged.

Leveraging the value of integrated data

The health care system is comprised of a broad variety of services all tasked with different patient care responsibilities. Workers who provide these services are all integral to the development of integrated electronic medical records, as they both enrich and refine data content through their persistent use of the system. Many health care practitioners readily identify similar personal workflow inefficiencies that hinder their care of patients. Experience has shown us that responding to those frequently identified deficits with informatics solutions yields great rewards.^{27,28} In other words, it's wise to identify informatics "hammers" for the biggest clinical "nails." Many of us at the Regenstrief Institute are trained clinician informaticians. Wearing both "hats" allows us to practically relate to these stakeholder needs while being cognizant of the limitations in current information technology. While developing these applications for clinical care, being mindful of their general uses as tools has also served us well. As we evolved into a city-wide information system, many of the tools constructed for the first generation system have been applied to the INPC dataset. This allows us to scale our system rapidly.

To further improve the likelihood of system adoption, we also provide these potential stakeholders with concrete evidence of how their "investment" in the system yields immediate, up-front payoffs. In the past 30 years, a significant portion of our efforts focus not only on system development, but in researching the impact that medical informatics has on the provision of care. We place high priority on published research in this regard.

Commitment to standards

Standards are the *sine qua non* of integrated medical record systems. Without them, it will be difficult, if not impossible to fully meet the recognized promises of electronic data sharing. The technical underpinnings of the INPC rely heavily on two types of standards. We use messaging standards such as HL7 to define data structures of content sent between systems. Code standards, such as LOINC and SNOMED, provide a way of representing medical concepts like tests and examination findings. Both types of standards give new INPC participants a way to "speak the same language" as the rest of our network. They also significantly reduce the amount of heavy lifting involved in the typical translational work involved during the connection process. Institutions can be prepared ahead of time to standardize to their content to these national standards. There's also an economy of scale on the receiving end of data, as interfacing software can be built once and reused for different systems.

Our goal from the start of the project was to fashion the Regenstrief Institute as a trusted, neutral convener.

Managing sociopolitical challenges

Entering into a data integration implementation without a keen understanding of the sociopolitical challenges specific to a community is a recipe for failure. Understanding this milieu within Indianapolis allowed us to create a political environment that fostered and encouraged participation in the network. We were fortunate to enter into this process however, with some significant advantages. Indianapolis, from the perspective of health systems enjoys a healthy sense of competition. As described previously, the Indianapolis MSA is served by 5 different hospital systems, and they all enjoy relatively equal footing. In addition, our reputation both as "helpful neighbors" within our community and as innovators nationally gave the initial participants a sense of trust in the concept as we posed it to them. Finally, we were able to secure grant funding that allowed us to conceptualize, build, and research a proof of concept system. This gave participants a real world prototype from which a top-down approach could later be facilitated.

Our goal from the start of the project was to fashion the Regenstrief Institute as a trusted, neutral convener. We worked with all participants to ensure they had equal footing at the negotiation table and removed first-mover advantages by ensuring equal access to the products of the system. Serving as this "data Switzerland" also implied that we treated all participating institutions with the same level of respect and timeliness.

As the INPC grows, our relationship to Indiana's public health system has grown to be increasingly important. Having both the largest county health department and the state health department headquarters within Indianapolis has allowed us to nurture a necessary relationship with public health stakeholders. This collaboration ultimately solidified into our Institution's designation as a legal "agent" of the state health department. This allows us to build future infrastructure on their behalf, which will likely be an evolution of our INPC model throughout the rest of Indiana. We believe this relationship with the state health department will be critical in the months and years to come.

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